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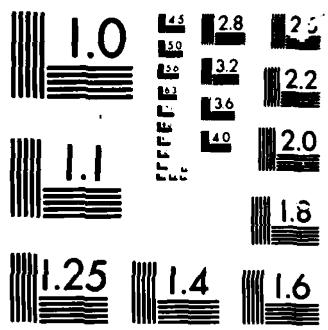

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The Terrain Analyst Work STation (TAWS) project was initiated by the U. S. Army Engineer Topographic Laboratories (ETL) to develop a prototype system to meet the Army requirements for providing timely and accurate terrain and environmental information used in making crucial tactical decisions. The TAWS prototype will incorporate off-the-shelf hardware and will adapt existing software to provide a capability to input soft and hardcopy source information, create, enhance and maintain geographic data bases, and generate hard and softcopy terrain and environmental products. The TAWS is intended to be operated by Army terrain analysts and will be demonstrated in the laboratory and in Army field exercises.

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THE TERRAIN ANALYST WORK STATION

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ABSTRACT

The Terrain Analyst Work Station (TAWS) project was initiated by the U.S. Army Engineer Topographic Laboratories (ETL) to develop a prototype system to meet the Army requirements for providing timely and accurate terrain and environmental information used in making crucial tactical decisions. The TAWS prototype will incorporate off-the-shelf hardware and will adapt existing software to provide a capability to input soft and hardcopy source information, create, enhance and maintain geographic data bases, and generate hard and softcopy terrain and environmental products. The TAWS is intended to be operated by Army terrain analysts and will be demonstrated in the laboratory and in Army field exercises.

1. TERRAIN ANALYSIS REQUIREMENTS

Terrain analysis is the process of analyzing military geographic information to determine the effect of the natural and man-made features on military operations. At present, terrain analysts manually assemble and analyze terrain information. These manual procedures are too cumbersome, slow, and inflexible to satisfy Army requirements for rapid generation, revision and dissemination of terrain information and terrain products. Present manual terrain analysis procedures require the analyst to collect data for the area of interest, (maps, imagery, reports, etc.), evaluate the data, (compare the data and select the most correct), prepare a factor overlay from the selected data, and if required, prepare a manuscript to accompany the factor overlay. This manual process can take an experienced analyst anywhere from a week to several months to complete one factor overlay. For these reasons, manual terrain analysis is a slow, tedious process at best and doesn't meet the Army's requirements for rapid product generation. To address this problem, the Army has been evaluating the utility of digital terrain data bases and automated terrain analysis systems.

Digital terrain data bases and automated terrain analysis techniques will help the Army meet the demand for quick, comprehensive terrain information. Many automated terrain analysis techniques have already been successfully demonstrated in the laboratory on an interactive computer graphics system known as the Digital Terrain Analysis Station (DTAS). Complex terrain products (cross-country movement maps and cover and concealment overlays) can be produced from prototype terrain data bases — and can be done in a fraction of the time required by the unassisted analyst. A planned Digital Topographic Support System (DTSS)

will make such techniques available to terrain teams in the field by the end of the decade.

Digital terrain analysis, however can only become a field reality if the appropriate data bases exist to support it. The Defense Mapping Agency (DMA) will supply digital topographic data to meet the needs of the terrain analysis community. Since U.S. military commitments span the globe, it would be difficult (if not impossible) for DMA to provide the Army with digital terrain information for every area that may eventually be of strategic or tactical interest. Even if complete coverage of the earth were possible, data base users would still find gaps between these general digital sources and the actual lay of the land -- particularly in battlefield environments. Modern combat techniques can change the face of the battlefield, making terrain information that was accurate yesterday obsolete in a matter of minutes.

Today's terrain analysts, working with maps, charts and other sources, must take such changes into account. Even after automation, troops in the field will still need to update and revise terrain data to reflect current conditions. The soldiers who man the topographic units of the future must also be equipped to create new terrain data bases should they be called upon to support combat operations in areas for which DMA data are not available.

In response to this need, scientists at the Engineer Topographic Laboratories (ETL) are assembling a prototype Terrain Analyst Work Station (TAWS). This terrain analysis demonstrator will showcase computer-assisted techniques for extracting, interpreting and displaying topographic information -- techniques which will eventually allow Army terrain analysts to produce, update and manipulate digital terrain data bases in the field. Although TAWS will essentially be a laboratory system, the incorporation of its capabilities into the planned DTSS will help make that follow-on development a fully functional automated topographic support tool.

The primary function of TAWS will be to perform data extraction, digitization, and mensuration. However, the work station will also incorporate certain data manipulation and product generation capabilities. The system will provide Army terrain analysts with the tools needed to: 1) create topologically valid digital terrain data bases using monoscopic and stereoscopic, multi-sensor imagery, graphics, text, and other military geographic information data sources; 2) edit, update, revise and intensify existing data bases; 3) merge data extracted from any of the data sources; 4) overlay features on digital elevation data; 5) manipulate, analyze and display digital terrain data in 2 and 3-D views; and 6) generate and disseminate Army battlefield tactical decision aids.

2. TAWS PROJECT DEVELOPMENT

One of the primary objectives of the TAWS exploratory development project is to demonstrate a fieldable terrain analysis capability as

quickly as possible. This required compressing the lengthy development time that is typical of fielding an operational system. Developers established a less than two year timetable from system concept formulation to the first field demonstration. Plans called for subsequent demonstrations to incorporate additional capabilities for the next three or four years as they are tested and accepted. The proposed TAWS concept called for utilizing off-the-shelf hardware and adapting and enhancing existing software to expedite the development. It seemed this would minimize costs and development time. However, the development process still entailed a considerable technical and programmatic effort.

The TAWS Geographic Information System (GIS) is software which was adapted from several systems. The software evolutionary predecessors to TAWS were written to utilize special features unique to their particular hardware configurations. Therefore, moving the software to a different machine or device configuration presented a very labor intensive and time consuming effort. Additional efforts were expended attempting to upgrade the documentation to a uniformly structured style. Some software components had never been tested under the variety of operational conditions that the TAWS might encounter. Therefore, remedial testing efforts had to be initiated as part of the project. Compounding the difficulties encountered in the software conversion effort, the TAWS project plans called for developing new capabilities of photogrammetric source extraction and digitizing on a custom built Light Table Mensuration System (LTMS) and creating enhanced product generation and analysis capabilities. Furthermore, because of the short development time, there was little, if any, slack time in the critical path of project activities. All programmatic and technical difficulties that resulted in activity delays had direct impacts on project completion milestones. (Despite these rigorous constraints, the TAWS met most of its initial development goals and met its first demonstration commitment in October 1985.)

2.1 TAWS SOFTWARE DEVELOPMENT GOALS

To meet the objectives of the TAWS project, a development strategy with specific goals was instituted. This strategy called for instituting modularity, portability and device independence in the software structure. The goal of modularity is intended to enable further software modifications or enhancements to be made at considerably less effort than was previously possible. It should also enable the TAWS capabilities to be used either as an integrated system or as a set of independent functional components. The goal of portability is intended to enable the software to run on a variety of computers requiring only minimal changes. Portability is a good strategic goal for TAWS for two reasons: 1) it encourages potential users to get copies of the software and to increase users exposure to digital technologies by not restricting them to using one particular computer; and 2) it makes development easier for any subsequent efforts that may occur on different computers to build upon the work accomplished under the TAWS effort. The goal of device independence is related to the goal of portability. Often, software code is written to be used to drive a particular device. If that device is modified, or exchanged for or enhanced with a different device, a substantial portion

of the code may require revision. Device independence implies that only a minimal number of routines need to be changed if the device configuration changes.

The problem of turning the code into a modular structure was tackled by segregating the software into functional groups and re-structuring the original programs. ANSI FORTRAN 77 was the primary GIS programming language utilized to increase portability. Additionally the UNIX (trademark of Bell Laboratories) operating system was selected to host the software. UNIX is commercially available through a number of vendors and supported by most micro and minicomputer systems. To achieve device independence, a requirement was instituted to isolate all calls to specific input/output devices in libraries and to eliminate device-specific graphics calls within the main applications routines. The requirements call for all applications programs to contain the ACM-Siggraph "Core" standard graphics calls.

3. TAWS HARDWARE CONFIGURATION

The TAWS computer is a 32-bit microcomputer with 5.0 megabytes of random access memory. It is supported by 264 megabytes of winchester disk storage, 440 megabytes of removable media disk storage and a nine track, 1600 BPI tape drive. The input/output devices consist of black and white and color graphics terminals, a color graphics plotter, a color ink jet copier and rasterizer, a line printer, a X-Y Digitizing Table, a Light Table Digitizing and Mensuration System. The system will be upgraded with an analytical stereoplotter in 1986, and may be enhanced with a scanning digitizing station in the future. The equipment will be installed in a tactical shelter in 1986 to facilitate its use in Army field demonstrations.

4. TAWS COMPONENTS

TAWS is comprised of four major components. These are data base development, terrain analysis and product generation, intervisibility analysis and product generation, and environmental effects software. The data base development and the terrain analysis and product generation components represent the TAWS GIS. The intervisibility analysis and the environmental effects components are software systems which allow the TAWS to be more diverse and flexible in providing terrain analysis products.

4.1 DATA BASE DEVELOPMENT

This first component allows users to create, update or revise digital data bases. Terrain teams can produce digital data bases by manually digitizing hardcopy overlays such as the Tactical Terrain Analysis Data Base (TTADB) (1:50,000) and the Planning Terrain Analysis Data Base (PTADB) (1:250,000) sheets. Digital data bases can also be developed from other source materials such as maps, charts, aerial photographs and textual information.

The TAWS system provides three basic instruments for data entry. These are an X-Y Digitizing Table, a Light Table Mensuration System (LTMS), and an Analytical Stereo Plotter (ASP). The X-Y Digitizing Table is for working with hardcopy graphics such as maps, charts or overlays. The LTMS is for digitizing feature data and making measurements from aerial imagery. The ASP is for producing elevation data from stereo imagery and making three dimensional measurements of terrain features. Of these three instruments, the ASP has not been implemented onto the TAWS system as of this writing.

An enhanced version of the Analytical Mapping System (AMS) is the software package used for the data base development subsystem. AMS is a computer-based mapping system for constructing a digital data base of geographic information by manually digitizing features found on maps or imagery. The primary purpose of the AMS software is to provide a comprehensive, sophisticated, and easy-to-use vehicle to enter digital geographical coordinate data. Once stored, this data can be reformatted and transferred to the Terrain Analysis and Product Generation component of TAWS.

AMS is designed to allow the digitization of geographical data, but is not limited to the digitization process. The primary functions of AMS are data entry, aerotriangulation, attribute assignment, digitizing, editing, and verification/polygon formation. Other capabilities include: graphic display, hardcopy and softcopy plotting, full data base storage and retrieval utilities, simultaneous user procedures, selection of twenty standard map projections, and an on-line crash recovery procedure. The data base development subsystem consists of photogrammetric, digitizing and verification routines.

The photogrammetric routines enable the analyst to interactively compute the camera and control point parameters of selected imagery. The digitizing routines enable the analyst to digitize from any of the data entry devices (e.g. X-Y Digitizing Table, LTMS, ASP). The analyst can digitize in any scale or orientation, create a data base in one of twenty map projections and then transform the data to another one of the map projections for analysis, and specify the size of the coverage for the data base. AMS also permits multiple overlays (themes) to be digitized for each project.

The digitizing operation is totally interactive with the operator viewing the displayed results in near real-time on a graphics terminal. The data is digitized in an arc-node format and the primary attribute information is entered at the time of digitization. Currently, no capabilities exist for entering in multiple attributes in the data base development subsystem. This has been recognized as an important capability for terrain analysis and is planned as an enhancement to the AMS software.

Once digitization is completed (actual features are formed from the arc-node-attribute data once digitizing is completed), each feature in a manuscript can be topologically verified. The AMS verification routines

check for various errors such as illegal or missing attributes, duplicate or kinked arcs, and slivers and gaps. Editing of arcs, nodes or attributes can be made either at the time of data entry or at a later time by querying the data base for a specific arc, node or polygon. When completed successfully, the verification routines confirm that a topologically valid maunscript has been compiled. Once this process is completted, the data can be stored directly in the data base where it is immediately available for analysis and display by the Terrain Analysis and Product Generation subsystem of TAWS.

The AMS software is designed to be user friendly and is menu driven. The user is led through the data base development process by a series of menus and prompts.

4.2 TERRAIN ANALYSIS AND PRODUCT GENERATION

This component of TAWS allows analysts to use automated techniques to study digital maps (created in the data base development component) and generate terrain products. The software packages which make up the Terrain Analysis and Product Generation subsystem perform many of the repetitious and time-consuming tasks and calculations involved in analyzing terrain data.

This TAWS component also provides the capabilities for analysts to "tailor" products to the user's needs. Typically, the analyst will call up the digital factor maps (digitized thematic overlays) for the area in question, manipulate the data to meet the user's requirements, save the results permanently if desired, and then plot an overlay or generate a report. Terrain analysis products generated by this component are divided into two categories. These categories are general terrain analysis products and mobility products. The general terrain analysis products include the following: concealment, avenues of approach, key terrain and engineering material sites. The mobility products incorporate various mobility models which include the following: cross-country movement, river crossing sites, bridge erection sites, and soil trafficability. Plans exist for additional models (created by other U.S. Army Corps of Engineers Laboratories) to be added to this component so additional products can be produced which will aid a commander in making tactical decisions.

The terrain analysis and product generation component of TAWS is supported by two software systems. These are the Map Overlay and Statistical System (MOSS) and the Map Analysis and Processing System (MAPS). As of this writing, the MOSS software has been implemented, tested and accepted on the TAWS system, with some corrections necessary. The MAPS software is in the process of implementation on the TAWS system. Testing of the MAPS software is scheduled after implementation is complete. Both MOSS and MAPS are analysis and display systems for map and other geo-based information and have been designed to allow non-technical users to retrieve, analyze and display maps, and spatial data stored in the system.

The major difference between the two software systems is that MOSS handles vector-formatted polygon data and MAPS handles raster (cell) data. Vector data consists of a series of (X,Y) coordinates which form points, lines or polygons. Each feature in a vector map may be assigned an identifying attribute based on its characteristics. Cell data consists of a regular grid pattern in which each cell in the grid is assigned an identifying value based on its characteristics. (Accuracy, resolution, storage and processing of cell maps are directly related to the grid-cell size which is user specified.) Cell data may be created from vector data, but currently vector data may not be created from cell data. Future GIS enhancements may include the capability for converting from cell data to vector data in the product generation subsystem.

The analysts choice of data format will largely depend on the final intended use of the data. In general, vector data are preferred for high precision cartographic output, whereas cell data are preferred for complex cartographic modeling procedures. Furthermore, standard elevation profile data available from DMA are in a grid cell (matrix) form. Therefore, complexing of elevation and feature data can be easily accomplished in the cell based system.

The data processing capabilities of MOSS and MAPS are organized as a series of individual commands which are functionally independent but which may be applied together as a system. These commands are specified and controlled through a user-oriented command language. MOSS accepts single word commands while MAPS accepts English-like phrases. Both assume no prior experience in computer programming. MOSS and MAPS commands are classified into four functional groups. These are: program control; data storage; data display; and data analysis.

The program control group of commands relate to the manner in which commands are performed or system parameters are set. These commands may be specified to utilize alternative input and output media, provide information about available commands, terminate processing altogether, or obtain information about system parameter settings.

The data storage group of commands provide the capability to add, access, and manipulate the map data base. Some of the commands are used to create and store entire maps while some are used to update parts of existing maps.

The data display group of commands provide the capability to display data sets. Depending on the command specified, map information may be displayed in tabular form or in the form of maps. Maps may be produced in alphanumeric form or in the form of line drawings. Display devices may be a graphics or alphanumeric terminals or hardcopy plotting devices.

The data analysis group of commands perform a variety of functions. These range from calculating and outputting tabular information, such as descriptive statistics, to reclassifying map information, to complexing or overlaying map data sets. These commands provide for the generation of new maps by combining and/or transforming values of existing maps and

represent the core of the terrain analysis and product generation component.

In actual practice, MOSS commands on the TAWS system have been broken down into three groups of operations. These are: general MOSS commands, MOSS analysis commands, and MOSS utility commands. General MOSS commands are responsible for program control and map data storage and description. MOSS analysis commands are responsible for extraction and production of information from existing map data, usually resulting in a new map. MOSS utility commands are responsible for general housekeeping and display of map files. The reason the MOSS commands are broken down this way is to accomodate virtual memory limitations encountered particular to the TAWS computer and to facilitate program swapping.

All of the information stored for processing by MOSS and MAPS is organized on the basis of individual maps. Collectively, maps are organized into projects. Each project includes several maps and types of maps stored in one area on a disk file. A maximum of 32,000 maps can be stored in each project. There are two types of projects: master and work.

Master project maps are generally original source maps that have been imported into the system. Master project maps cannot be overwritten, deleted, renamed, or altered in any way, and can only be accessed and read.

All derived maps, maps that are made by the user, are placed in a work project. Work project maps eliminate much of the time and expense required to regenerate data sets that will be used repetitively over a period of time. Unlike master project maps, work project maps may be amended, deleted or renamed.

4.3 INTERVISIBILITY ANALYSIS AND THE BATTLEFIELD ENVIRONMENTAL EFFECTS SOFTWARE (BEES)

In addition to the TAWS GIS (data base development and terrain analysis components), the TAWS supports specialized terrain analysis software for planning military operations. These systems are the Intervisibility Analysis and Product Generation software and the Battlefield Environmental Effects Software (BEES).

The intervisibility analysis products are generated from digital elevation matrices compiled on TAWS or from the Defense Mapping Agency (DMA) Digital Terrain Elevation Data[1] (DTED). The intervisibility products are used to determine areas that are visible, either optically or electronically, from a given site. The software also compensates for earth curvature and atmospheric refraction and can optionally incorporate

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[1]The DTED provided by DMA is terrain elevation data recorded on 9-track magnetic tapes and are available for most areas of interest to the Army.

vegetation heights into the analysis if this information is available.

Seven intervisibility models are presently available on the TAWS system. These models are Line-of-Sight, Perspective View, Radial Terrain Masked Area, Target Acquisition, Multi-site Target Acquisition, Composite Multi-site Target Acquisition, and Color Contour Elevation.

The Battlefield Environmental Effects Software (BEES) is a series of interactive computer programs designed to aid command and staff personnel in characterizing the environment of the battlefield and in determining the environmental effects on equipment, personnel and operations. BEES is intended to aid the long-term planner as well as support the functions of the terrain analyst and the intelligence staff during exercises and actual battlefield operations. The programs are classified into six functional groups. These are: Historical Climatology, Operations, Almanac Functions, Mobility, Engineering, and Utility.

5. TECHNOLOGY ASSESSMENT

In October of 1985 the TAWS was taken out of the laboratory environment to the field for a first demonstration. The first demonstration took place in a garrison at the 1st Armored Division (1AD) in Ansbach, Germany. This demonstration was a combination of a capabilities and a production demonstration showing the 1AD how to generate intervisibility products for their area of interest.

The demonstration provided three main benefits. First, ETL researchers gained valuable feedback from field users concerning the system's ease of use, techniques and methodologies employed in the software, and usefulness of the wide variety of products provided by TAWS.

Secondly, 1AD obtained a large number of terrain analysis overlays for their use. Numerous unique overlays were produced during the demonstration in addition to large amounts of environmental data provided by BEES.

Lastly, Army terrain analysts received a good understanding for the type of automated topographic system they will be using when the Digital Topographic Support System is fielded.

During the demonstration, a total of six terrain analysts received training on the TAWS system. Seven days were dedicated to hands-on training and five days were dedicated to product generation and additional data creation by the trainees. At the end of the demonstration, the trainees were given a comprehensive questionaire which provided each trainee an opportunity to evaluate the individual components of TAWS and the overall TAWS system.

The general response from the trainees was very positive. The trainees believe the TAWS would be a welcome tool for the Army terrain units and that a TAWS would allow them to perform their jobs faster and improve their overall job performance. They were also pleased to see that

many of the tedious and repetitious operations that they perform manually can be done by the TAWS system. Regarding the usefulness of the products produced by TAWS, all the trainees agreed that the products would be useful and beneficial to their needs. They especially liked the flexibility the GIS offered which enabled them to tailor products to their specific needs.

In terms of adjusting to computer-assisted terrain analysis, the six trainees had mixed emotions (the trainees had limited, to no computer experience). Some of the trainees caught on quickly while others had considerable difficulty. The trainees had very little difficulty adapting to the menu driven components (data base development, intervisibility analysis, BEES), and said that they were very "user friendly". The command driven component (terrain analysis), on the other hand, did cause the trainees some difficulty. The overall feeling for the terrain analysis component was that it required too much computer knowledge and was not very "user friendly". To a certain degree, this was expected because the analysts were only given a very short amount of time to learn to use the commands.

Based on the feedback from the trainees and on the perceptions of the ETL researchers, many valuable comments, suggestions and recommendations were made concerning the TAWS system and the demonstration. All participants expressed a concensus of opinion that the TAWS first demonstration was a success.

Upcoming plans for the TAWS in 1986 include photo extraction capabilities, placement of equipment in a Tactical Shelter (Figure 1) and several field demonstrations. The TAWS will also begin to develop and incorporate enhanced GIS features.

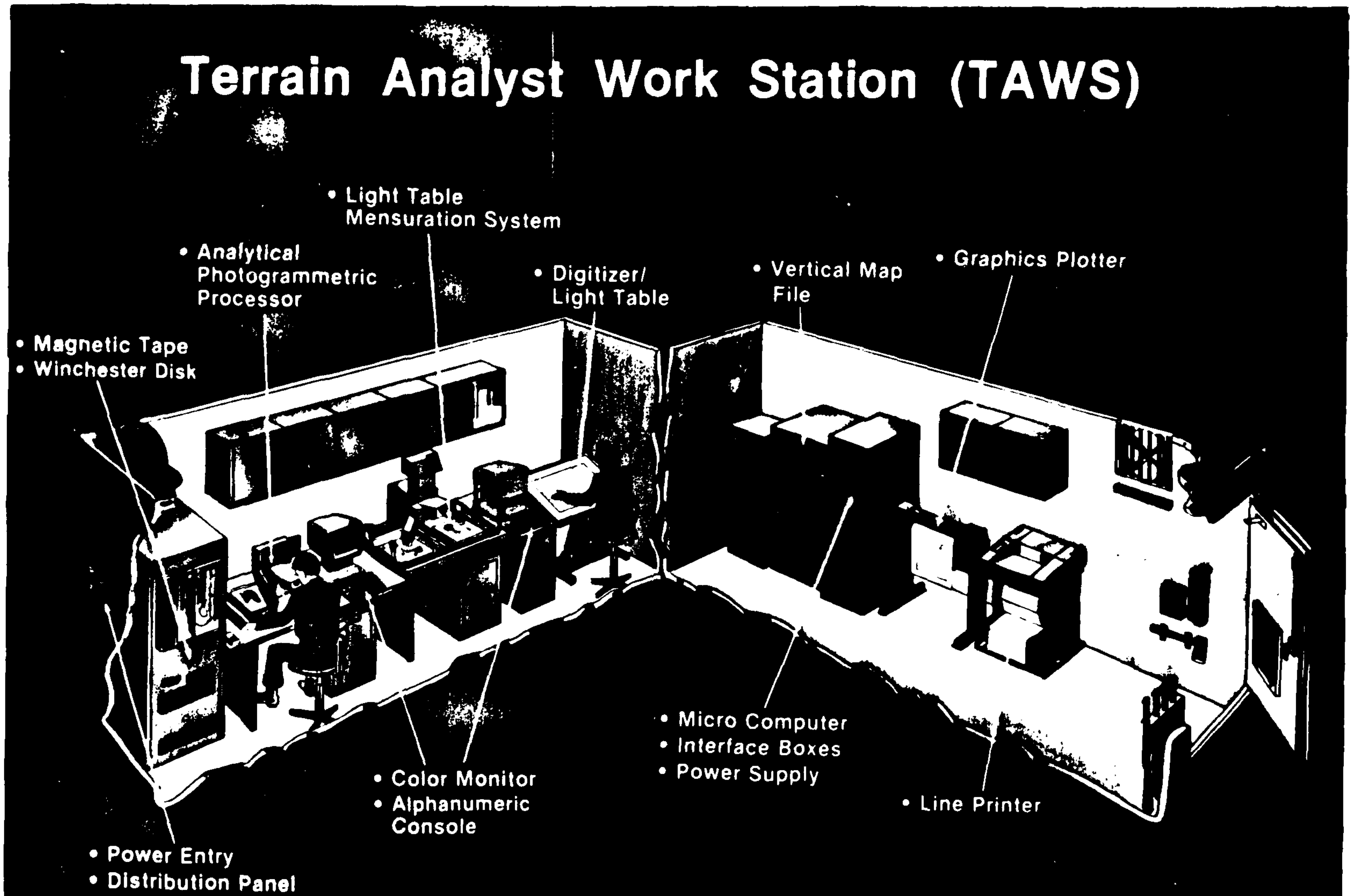

FIGURE 1. Artist concept of the TAWS in a tactical shelter.

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